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EXECUTIVE SUMMARY

This qualitative[1] evaluation report examines the implementation of the Office of Space Science (OSS) Education and Public Outreach (E/PO) strategy, developed in 1994–1995, to make “education at all levels and the enhancement of public understanding of science integral parts of space science research activities.”[2] The goals of the OSS E/PO Program are outlined in the current OSS Strategic Plan.[3]

- To share the excitement of space science discoveries with the public
- To enhance the quality of science, mathematics, and technology education, particularly at the pre-college level
- To help create our 21st century scientific and technical workforce

The OSS E/PO Program has made significant advancement toward all three goals.

OSS has found a number of ways to **share the excitement of space science**, via television, the press, public science talks, and a variety of other strategies.

- OSS has developed strong relationships with many large museums and science centers. OSS scientists and E/PO staff have collaborated with museum staff to create several successful museum exhibits.
- OSS has also been developing relationships with smaller museums. Small museums and science centers benefit from OSS data presented in adaptable formats. Museum staff can then use the data to create resources appropriate to the physical limitations of the space and the educational needs of the community they serve.

The OSS E/PO Program has been instrumental in the development of a variety of resources that **enhance the quality of education**.

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1 Qualitative analysis allows for deep exploration of a variety of areas, and can uncover a range of perspectives that are *present* in the population of interest. Unlike quantitative analysis, however, qualitative analysis cannot be used to estimate the prevalence of any specific variable.

2 *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA’s Space Science Programs*, 1995, p.1

3 *The Space Science Enterprise Strategic Plan*, 2000 (p. 23)

- The OSS E/PO Program has developed or contributed to the development of a variety of space science educational resources.
- The Support Network (SN) has developed a Space Science Education Resource Directory (SSERD) which catalogs a wide range of electronic resources available to educators.

The OSS E/PO Program is developing awareness that **the 21st century workforce** must reflect the 21st century population, a population that is becoming increasingly diverse. The OSS E/PO Program has taken strong steps toward forging relationships with a diverse population.

- The OSS Minority University Initiative provides funds for minority universities, which traditionally have been neglected by the space science community.
- The SN has hosted several events for members of minority professional organizations, leading to the development of several important collaborations.
- The OSS E/PO Program has produced materials that are accessible to audiences that have traditionally been underserved by NASA, including non-English speakers and the differently-abled.

One important feature of the OSS E/PO Program is the Support Network (SN), a network of institutions across the nation that are charged with supporting the E/PO mission. The SN has been instrumental in the above-mentioned successes. Perhaps the most important step that the OSS E/PO Program has taken is the broadening of communication between the SN and the audiences it is intended to serve. Data indicate that the more opportunities these audiences have to communicate about their needs and challenges, the more effectively the OSS E/PO Program can meet these needs.

Although the scientific community has not yet fully embraced education as a worthwhile vocation for scientists, a growing number of individuals and institutions are beginning to recognize its value. However, the culture of science remains an impediment to the development of E/PO.

- For scientists, traditionally, both funding and prestige have been tied to research alone. Working in education has been viewed as a distraction from the real work of science. OSS is addressing this issue by acknowledging and supporting scientists who make significant contributions to E/PO.
  - By mandating that each mission must spend 1–2% of its budget on E/PO, the OSS administration has created a structure that allows for the embedding of education within OSS missions.

- Evidence suggests that this funding mandate has led to the scientific community's increased acceptance of EPO development as a legitimate activity for scientists to engage in.

- While the OSS E/PO Program has had success embedding E/PO into missions, it has struggled to embed E/PO into smaller research projects. Scientists report that the proposal process is complex, cumbersome, and confusing. OSS is taking steps to address these issues. Data indicate that communication with the scientific community about how their concerns have been addressed is important for the acceptance of any new proposal process.

- Many scientists erroneously believe that they must become experts in education, and devote extensive time to E/PO, to make a significant contribution. Data indicate:
  - Scientists benefit from support in forging collaborations with educators and resource developers who can provide pedagogical expertise to match the content expertise the scientists provide.
  - The OSS E/PO Program can help scientists understand that they have options beyond becoming experts by providing more information about activities that would allow them to contribute their knowledge without a large time commitment, such as participating in an existing program, reviewing a resource for accuracy, or giving a short presentation.

OSS is working to better understand the needs of educators. Data indicate that gathering information from teachers about their needs can support the development of appropriate resources and the integration of space science into the classroom.

- Schools' limited financial resources pose a challenge to getting space science into the classroom. These limitations affect teacher professional development, time available for teaching space science, and access to space science resources.

- At present, many of the materials created by OSS to serve the formal and informal education communities are electronic. These resources have the potential to reach a wide audience, and are inexpensive and easy to distribute. However, there are two important limitations to electronic resources:
  - They are inaccessible to many communities, especially those that have been traditionally underserved by NASA.
  - Resources that rely on electronic media to supply information in a time-sensitive fashion are vulnerable to failure at points of transmission, reception, and delivery.

- Production and distribution of hard-copy materials continues to pose a challenge for the system. The OSS E/PO Program is exploring channels to meet this challenge. There may be no easy and inexpensive solution to the distribution problem. Because of the diversity of needs and challenges, a multi-pronged approach may be necessary.

- The pressures of national and regional standards, and the high-stakes tests that accompany them, are having a profound effect on the classroom.
  - Teachers do not have the option of spending time exploring material that is not aligned with standards.
  - Because standards may vary from state to state or district to district, many teachers explain that they need materials that are adaptable and can be altered to fit into their curriculum.
- Many teachers (especially at the elementary and middle school levels) are underprepared to teach science.
  - Working with scientists, either at OSS workshops or in their own classrooms, can provide teachers with the knowledge and confidence they need to teach space science effectively.
  - Teachers benefit from materials that are cognitively accessible and provide adequate background information on relevant topics.

Scientists and educators both benefit from direct experience with each other, and with each other's environments. The necessity of providing an opportunity for scientists and educators to work together toward a common goal remains a key issue. This is an area where members of the SN can and do play an active role, both in providing opportunities for members of the two communities to interact and in helping them to understand each other. By allowing scientists and educators to come together, the OSS E/PO Program is helping to develop much-needed opportunities for interaction between the two communities, thus supporting the development of E/PO resources that meet both the needs of educators and the standards of space scientists.

INTRODUCTION

From its inception in 1958, the National Aeronautics and Space Administration (NASA) has sustained an agency-wide commitment to education. During the period 1994–1996, the NASA Office of Space Science (OSS) developed Education and Public Outreach (E/PO) Strategic and Implementation Plans to support this commitment by developing a variety of E/PO resources and integrating them with existing efforts to create a coherent vision. The Implementation Plan specifically addresses the methods by which the goals articulated in the Strategic Plan can be realized.

EVALUATION

The Program Evaluation and Research Group (PERG) of Lesley University contracted with the NASA Office of Space Science in October 1998 to conduct an external evaluation to determine how effectively OSS is carrying out its E/PO Implementation Plan. This report is the second in a series of three evaluation reports.

- The first report focused closely on the infrastructure of the OSS E/PO Program,[4] especially the Support Network (SN), a network of institutions across the nation that help achieve the goals of the OSS E/PO Implementation Plan. The first report dealt with variables affecting the SN itself. Thus, the data analyzed were collected primarily from members of the OSS E/PO community. Data were collected between November 1998 and October 1999, and the report was delivered in May 2000.
- This second report focuses on implementation. Data for this report were gathered between January 2000 and May 2001, both from members of the OSS E/PO community and from the communities it serves directly (educators, scientists, the rest of NASA). This report focuses on the actions that the OSS E/PO Program is taking to meet the goals outlined in the Implementation Plan, the successes of the Program, and the challenges that it faces.
- The third report will focus on the impact of OSS's E/PO activities. Data will be gathered from the populations included in the first two reports, as well as from end-users of NASA products (e.g., teachers who participate in OSS teacher-training programs, visitors to OSS museum exhibits, etc.). Analysis will explore

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[4] In this report, we use the term "OSS E/PO Program" to refer to the individuals and organizations that participate in or contribute to the creation of OSS E/PO material, and all activities carried out in support of the OSS E/PO Strategic Plan.

the effect that OSS's E/PO efforts are having on the audiences it is intended to serve. We are currently beginning data gathering for this report, which we plan to issue in approximately eighteen months.

THIS REPORT

This report describes the OSS E/PO Program during the period of January 2000–May 2001 and proposes recommendations for strengthening the Program as it moves forward. Although the primary focus of this report is implementation, it also touches upon infrastructure (which is necessary for implementation) and upon impact (the result of implementation).

The findings are divided into two sections. The first section describes the cultural contexts of the scientific and educational communities. These contexts are discussed in their relation to the OSS E/PO Program, and the challenges presented by the differences between the two cultures. The second section examines the specific activities of the Program and addresses successes and challenges in regards to each goal.

The data presented in this report are *qualitative*. Qualitative data allow for deep exploration of a variety of areas, including many that are uncovered during the data collection process. Analysis of qualitative data can uncover ideas, beliefs, attitudes, challenges, etc. that are present in the population of interest. Unlike quantitative analysis, however, qualitative analysis cannot be used to estimate the prevalence of any specific variable, because the data are not representative of the larger population beyond the participating sample. Thus, while our analysis can reveal, for example, beliefs that some scientists hold about education, our analysis *cannot* give any indication of *what proportion* of scientists hold a specific belief.

Throughout the report, there are citations from the data. They are not attributed to specific settings and speakers; rather, they are included to add context and richness to the discussions and to illustrate the perspectives of those engaged in the work. All data cited in the report have been selected to *represent the themes and trends* that emerged from the data and are characteristic of the *perspectives voiced by multiple respondents* and issues related to the program during the report period. However, they do not indicate that each individual (or a majority of individuals) in the total community beyond the sample group shares the same perspectives.

Also included in the report are vignettes that illustrate specific discussion points; in many cases the vignettes describe resources developed with the aid of the OSS E/PO Program. These vignettes are only a small subset of the activities and successes of the OSS E/PO Program. They have been selected to represent a range of activities, and while they represent successful activities on the part of the OSS E/PO Program, they are not necessarily the only successful, or most successful, resources developed. Individuals and organizations are not identified unless the identification has been permitted by the staff and is essential for the discussion.

PARTICIPANT AUDIENCES

For this report, we gathered data from a wide range of individuals. The types of people whose comments, ideas, and concerns are reflected in this report include:

- Members of the OSS Education Council—this includes the SN, as well as OSS E/PO administration, and staff from NASA's Code FE (Education) and Code EU (Minority Universities)
- OSS E/PO Personnel—this includes staff working on E/PO within OSS missions, E/PO developers associated with OSS research projects, and others playing important roles in the creation of OSS E/PO
- NASA Education Division (Code FE) staff
- Scientists—this includes mission scientists, research scientists, and discipline scientists; scientists interviewed include NASA civil servants, employees of organizations working with NASA, and university professors, among others
- Formal and Informal Education Personnel—this includes K–12 teachers, museum staff, librarians, and others engaged in the process of educating the public
- Other OSS E/PO Partners—these include publicly- and privately-funded organizations and individuals who have worked with OSS personnel to create space science education resources
- Space Science Education Providers beyond OSS—these include publicly- and privately-funded organizations and individuals who have created space science education resources without input from OSS personnel

The individuals interviewed formally and informally are described in Table 1 on the following page.[5]

[5] Many participants fall into more than one category. In general, they were counted in the role that was most relevant to their OSS E/PO work. In particular, participants were only classified as "OSS E/PO Partners" or "Non-NASA E/PO Providers" if they did not belong in any other category.

Table 1: Participant Audiences

Audience	Formal Conversations	Informal Conversations (approximate #'s)	Total (approximate #'s)
Ed Council	11	All others (50)	61
OSS E/PO	27	20	47
Code FE	17	3	20
Scientists	53	30	83
Educators	27	30	57
OSS E/PO Partners	2	5	7
Non-NASA E/PO Providers	6	10	16
Total	**144**	**148**	**292**

EVALUATION METHODS

Evaluators conducted formal interviews with approximately 300 individuals who have interacted with or been affected by the OSS E/PO Program in various ways (see list above). Interviews have taken place in person or by phone. In many cases, follow-up phone conversations or e-mail exchanges have supplemented these. Evaluators have maintained communication with Education Council members (including the Assistant Associate Administrator and administrative staff), attending Education Council meetings, observing the plenary sessions and selected Working Group meetings, and providing formative evaluation on an ongoing basis. Evaluators attended events hosted by the SN and/or its component institutions. At these events, evaluators observed interactions, interviewed participants, and provided formative feedback as appropriate. Evaluators also attended a variety of scientific and educational conferences with a strong OSS E/PO presence. At these conferences, evaluators observed OSS presentations and engaged participants in informal discussions on topics relevant to the evaluation.

In addition, evaluators have visited all of the SN institutions; have reviewed a range of OSS documents, including the Strategic Plans, 2000 Annual Report, and Space Science

Education Resource Directory (SSERD); and have participated in telecons. Throughout the evaluation process, the evaluators have exchanged phone calls, e-mail, and memos with staff about a range of issues, activities, and events.

PROJECT DESCRIPTION

The OSS E/PO Program is dedicated to realizing the goals of the Implementation Plan, which was developed with the mission of making "education at all levels and the enhancement of public understanding of science integral parts of space science research activities."[6] The intent was to build a bridge between OSS and the public, particularly the formal and informal educational communities. The goals of the Program are outlined in the current OSS Strategic Plan:[7]

- To share the excitement of space science discoveries with the public
- To enhance the quality of science, mathematics, and technology education, particularly at the pre-college level
- To help create our 21st century scientific and technical workforce

Virtually all OSS E/PO is funded through OSS missions and instrument programs, through grants for Supporting Research and Technology, and through the activities of the SN.[8] OSS guidelines require that scientific staff be involved with the development of E/PO related to their missions and research. Scientific staff are often supported by personnel dedicated specifically to development of E/PO resources.

One of the main actions of the OSS E/PO Program was the development of a Support Network (SN) comprising four Forums and five Broker/Facilitators[9] (B/Fs). The Forums correspond to OSS's four themes (Solar System Exploration, Sun-Earth Connection, Structure and Evolution of the Universe, and Astronomical Search for Origins). As every OSS mission is aligned with one of the themes, the Forums reach every OSS mission.

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6 *Partners in Education: A Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs*, 1995, p.1

7 *The Space Science Enterprise Strategic Plan*, 2000 (page 23). Note that the original implementation plan had four goals, which have been reframed into the current goals as a result of input from the larger space science and educational communities.

8 There are a few smaller grants programs, such as IDEAS, that provide E/PO funding that is not tied to specific NASA missions or research projects. However, these represent a very small proportion of the OSS E/PO budget. In addition, Guest Observer Grants (which support guest scientists on missions) may involve E/PO components.

9 At present, proposals are being reviewed for B/Fs for the upcoming round of funding. It is likely that the number of B/Fs will increase as a result of this activity.

The B/Fs are spread across the nation; they were originally conceived as working regionally with users of OSS's educational products and identifying the needs of the populations served by the OSS E/PO Program. The Forums and B/Fs (the SN), together with personnel from OSS (Code S), NASA's Education Division (Code FE), and the Minority University Research and Education Division (Code EU), form the basis of the OSS Education Council—the group created by OSS to ensure coordination of E/PO efforts and carry out a variety of critical OSS-wide support activities. The OSS E/PO Program and the SN are described in detail in the first evaluation report (delivered in June 2000). Interested readers are referred to that document for information beyond that given in this report.

The SN has provided a variety of useful services since its inception; many of these are highlighted in the first report. As a consequence of SN activity, the OSS E/PO Program as a whole has increased in connectivity and integration. During the period covered by this report, the system was engaged in a variety of activities. The SN and its components continued and expanded the work it had been involved with over the previous years, including outreach to the educational and scientific communities, development and implementation of educational resources and systems, refining the SN infrastructure, and coordinating actions with NASA's Code FE. In addition, several important new activities began. These include developing the Space Science Education Resource Directory (SSERD); publishing the first Annual Report; developing and distributing internal and external newsletters cataloging significant E/PO activities; developing the first Minority University Education and Research Partnership in Space Science Initiative; meeting with representatives from several minority professional organizations; and planning the first OSS E/PO conference, which will bring together scientists and educators, provide professional development opportunities, and highlight some of the successes of the OSS E/PO Program.

SPACE SCIENCE AND EDUCATION: BRIDGING THE CULTURES

The OSS E/PO Program serves, partners with, and is accountable to a variety of individuals, organizations, and institutions. These range from the highest political offices (including the White House and the OMB[10]) to the most local of all entities, the classroom. One of the largest challenges that the OSS E/PO Program faces is coordinating its activities with, and satisfying the demands of, the various masters it serves. Over time, the OSS E/PO Program has developed skills and strategies that allow it to interact more effectively with a range of constituencies. The OSS E/PO Program has made significant progress in working with its audiences and has achieved a variety of successes. Throughout this report, framed text boxes provide examples of the types of activities that the OSS E/PO Program is engaging in. The SN has played an important role in these activities and has been instrumental in building bridges between the space science and educational communities.

For many scientists, the culture of science remains an impediment to their work in education. While efforts by the OSS E/PO Program have led to significant improvement, there is still resistance to involvement with E/PO. In particular, many scientists mistakenly believe that they must become experts in education if they are to make a significant contribution to OSS E/PO. The OSS E/PO Program is working to correct this misconception by developing and communicating methods whereby scientists can make (and be recognized for) contributions to E/PO in ways that do not make undue demands of their time and energy. Data indicate that supporting and expanding these efforts will make E/PO attractive and accessible to a wider range of scientists.

Given the demands of a research career, scientists need support if they are to take time to work on E/PO development. The decision to devote 1–2% of each mission's budget to E/PO has provided scientists with the resources to create meaningful E/PO products. Efforts to embed E/PO in the missions has worked well, while efforts to embed E/PO in OSS research programs have been less successful. The approaches to embedding E/PO in research programs are currently being examined, and there needs to be some energy devoted to deciding if and how they should be continued and altered.

To best utilize their own knowledge, and to feel good about the resources they are creating, scientists must be able to access the expertise and experience of those involved

[10] Office of Management and Budget

in education. Whether they are working directly with educators or simply providing access to information and data that educators can use, scientists benefit from knowledge of the culture in which educators work and live.

One of the biggest challenges faced by the OSS E/PO Program is the lack of direct knowledge about the needs of educators. Most scientists have little experience in classrooms or museums, and do not fully understand the types of resources that would be useful in these environments. Various components of the OSS E/PO Program have reached out to educators, working to find out how OSS can best meet their needs. These activities have yielded helpful information. For example, by talking with K–12 teachers, OSS has become increasingly aware of the difficulty many schools face in accessing electronic resources. Because most scientists have access to near state-of-the-art equipment, those who are not in communication with teachers may not realize the limitations that many schools face in terms of access to the Internet. By fostering relationships between scientists and educators, the OSS E/PO Program plays an important role in increasing awareness within both communities.

One of the primary activities of the SN has been to establish partnerships that link the space science and educational communities. In the 1995 OSS document, *Partners in Education*, one of the original goals of the OSS E/PO Program was to:

> facilitate and cultivate strong lasting partnerships on local, regional, and national scales between the space science research and development communities and the professional communities in science, mathematics, and technology education.

These partnerships are the bases on which many of the E/PO activities are built. One of the challenges to the OSS E/PO Program is that the two communities differ greatly in terms of culture, philosophy, and language.

> There are problems in the different philosophies and approaches of scientists and educators. So, there's a lot of conflict that needs to be resolved. Scientists seem to think that the science should be first and we've all been educated so we know all about it. Educators think that scientists don't know anything about how children learn. Also, scientists tend to be more aggressive when they disagree with something. It's a different approach. Educators see strong criticism almost as an insult and that's not how it is meant. They can get defensive. It's a necessary learning process for everyone involved. (Mission scientist)

OSS's goal of linking the communities is not an easy one to reach. It is, however, a goal that our data indicate is achievable, and one that *must* be reached if OSS is to achieve its E/PO mission. Since the OSS began implementing its E/PO strategy, there has been increasing recognition of the importance of these linkages among a variety of audiences, and slow but significant movement toward integration. Both scientists and educators report specific instances where they have been successful in communicating with each other across the cultural divide. In many cases, they recognize the contribution of the OSS E/PO Program, and the SN in particular, to improved communication.

> I really enjoy working with the teachers. I enjoyed meeting the people who are teaching our children. Sort of a humanistic aspect I enjoyed the most. (Research scientist)

> It's useful having time to spend with people who are doing astronomy and space science. That's an important first step in making any changes. People who I can respect professionally. I can continue to talk to them and seek them out in other places. (High school teacher)

> My participation in the Ecosystem[11] has helped in keeping my eyes open to the wider world. If I hadn't been going to the [Education] Council meetings, I don't think I'd be as aware of what's going on. (Mission scientist)

The next three subsections of this report build on and amplify the points above. They describe in more detail the worlds of the space scientist and the educator, the problems that space scientists face in becoming involved in E/PO, and the issues faced by educators that must be understood by the space science community if it is going to become an effective contributor to education.

THE SPACE SCIENCE COMMUNITY

Space scientists describe research and mission development as highly competitive. NASA has a complex set of policies and practices that emphasize and reward individualistic approaches to space science, which tends to inhibit cooperative or collaborative ventures. In addition, the pressure to produce scientific research results is intense. Some scientists we spoke with believe E/PO should be the responsibility of staff assigned exclusively to that activity. Others are enthusiastic about getting involved with education, but recognize that the costs of taking time away from research to do E/PO are high. Several recognize that there has been greater acceptance of E/PO work within the scientific community over the past few years.

Data indicate that the increased acceptance is related largely to funding decisions. Now that there has been an administrative mandate from OSS that each mission *must* provide resources for education, E/PO is gaining value in the eyes of the scientific community. The OSS E/PO Program, particularly the SN, has been pivotal in communicating the importance of education to the space scientists who have knowledge and expertise to contribute to the creation of quality resources. There has been a good deal of support for

[11] The OSS E/PO Program was originally referred to as "the Ecosystem."

E/PO within missions, which has led to the development of some very successful resources. The efforts to incorporate E/PO into smaller Supporting Research and Technology programs have been less successful, and these efforts are currently being re-examined.

FUNDING

Regardless of how well OSS communicates with space scientists about doing E/PO, our data indicate funding policies convey NASA's priorities to the space science community. As noted in the original Implementation Plan, "Funding is the sincerest form of flattery."[12]

OSS's decision to dedicate 1–2% of its budget to education has made a significant difference in the way that scientists view E/PO. This policy shift has had the effect of justifying the time, energy, and resources that space scientists expend on E/PO.

> Missions now place 1–2% of the funds for education, and it has to be *good* education. So now, if you want a mission, you better get a good education program together. So, it becomes valued. (Research scientist)

The bulk of OSS E/PO is funded through space science missions, each of which is required to develop and support E/PO related to its research focus and findings. In addition, E/PO funding is available within the Supporting Research and Technology programs, for which opportunities are provided to add E/PO elements to research grants.

The effort to embed E/PO in the large missions has been relatively successful. Certain missions—such as the Hubble Space Telescope and Chandra —have produced exemplary, award-winning materials for classrooms, museums, and teacher training. Their success is probably related to several important aspects of the mission E/PO efforts:

- The amounts of money involved are quite large. Mission budgets generally range from tens to hundreds of millions of dollars. E/PO accounts for 1–2% of the total budget—a significant amount of money.

- The final E/PO proposal is generally the result of collaboration between scientists and E/PO staff working together to develop a strong proposal. In some cases, members of the SN are enlisted to assist with the E/PO design.

> I should point out that the AO [Announcement of Opportunity] proposals generally come from consortia. The PI [Principal Investigator] for one of these

[12] *Implementing the Office of Space Science Education/Public Outreach Strategy*, 1996, p. 17

> missions is in charge of the whole thing . . . The second member is a national laboratory; [the third is] an industrial partner; a fourth member is one of these E/PO providers. (Program scientist)

- While OSS guidelines require that scientific mission staff remain involved with the E/PO component, most missions employ dedicated E/PO staff. The E/PO staff gathers information and transforms it into the planned products, events, and services destined for K–12 education, higher education, museums, and the public. The scientific and technical staff is responsible for assuring the accuracy of these resources and providing scientific expertise.

Attempts to embed E/PO in the smaller Supporting Research and Technology programs have been significantly less successful. This may be related to the level of funding. Grants for Supporting Research are relatively small. Scientists who apply for these grants, through NASA Research Announcements (NRAs) may also apply for E/PO funds beyond the amount allocated for scientific research or technological development. The amount allocated for the E/PO of any given project does not exceed $10,000 per year, a figure many proposal writers consider trivial, especially given the amount of time and energy needed to prepare the proposal.

> $10,000 or less, which is the size of most NRA E/PO components, isn't enough to do anything worthwhile. The balance between production of proposal and their administration is way out of whack. It takes more time and money to get and administer a proposal than the value of what is to be done. (Research scientist)

The NRA review process has been plagued with difficulties, leading to a great deal of frustration on the part of scientists who included E/PO sections in their proposals, but who were neither funded, nor given sufficient feedback about *why* they were not funded.

> You had to send out hundreds of letters—you're trying to encourage people to do E/PO, and then you send out in response to their E/PO message hundreds of letters saying "You're non-compliant; we're not even going to review it."(Discipline scientist)

Some scientists, especially those who had submitted E/PO proposals for the first time in 1999 or 2000, express an unwillingness to be involved in the process in the future.

> It's not clear how I can successfully do an E/PO proposal in conjunction with my small grants proposal. It seems like it might be easier to do E/PO on my own than to figure out how it's supposed to work and do the proposal work.(Research scientist)

> It's tough, because if people submit a proposal, and they get rebuffed, they won't submit again. (Discipline scientist)

As a result of communication from the scientific community, the NRA process is currently being substantially revamped. In the past, quality E/PO proposals had been submitted with research proposals that were not accepted and therefore were not considered for funding. Those E/PO proposals attached to non-funded research proposals represented a significant outlay of time for both proposers and reviewers.

Scientific proposals submitted in response to NRAs for 2001 were not expected to include an E/PO component as part of the original proposal. Investigators whose scientific proposals are accepted will be sent an invitation to submit a proposal for an additional E/PO component. As of the end of data collection (May 2001), several changes were still being discussed and the guidelines have not yet been released to the scientific community[13]. It is too soon to determine if these changes will be effective in motivating more research scientists to become involved with E/PO.

INCORPORATING E/PO INTO A SCIENTIFIC CAREER

There are still scientific cultural issues that discourage scientists from becoming involved with E/PO. Many scientists involved with E/PO describe themselves as being pulled in two directions. Being a successful scientific researcher is a full-time job; so is being an educator. Some scientists working part-time in E/PO see themselves as serving two masters. Our data indicate that many scientists have difficulty finding the resources to serve both masters well.

> Scientists who work in science education run the risk of not being seen as someone doing science. They have to have intensive periods where they go to meetings, publish lots of papers, focus on the science. It's difficult to do two jobs. (Research scientist)

> It's extremely difficult to maintain a career doing 30–40% public outreach, because you can't maintain a research career at 60%. You either have to drop down to dabbling in E/PO so you can bring in the research money, or devote yourself to being an E/PO person on E/PO money. (Research scientist)

Despite the scientific community's emphasis on pure research, our data indicate that some researchers who are able to secure funding for education are seen as beneficial to their institutions. The contributions they are making to E/PO are valued.

> I think they've helped my career. They've made me more valuable to my own university. I come from a university that doesn't have a strong research presence and with [the SN's] help, I was able to write three strong grants. You get noticed. (Professor/research scientist)

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[13] These guidelines are slated to be released in August 2001.

> My career wouldn't suffer by doing E/PO work now. You can show that it is a valid part of the program. In recruitment of new science faculty here, E/PO is now a major issue. It is seen here as invaluable and my colleagues also view it that way.
> (Professor/research scientist)

Not all institutions are so supportive of time spent on E/PO. The competitive culture of research science requires that scientists protect their research ideas from each other to compete for funding. Science work is scrutinized by the community for its contribution to the field. Scientists make their way through the ranks based on their science successes and contributions.

> We're not evaluated on E/PO, so if I spent 10–15% of my time on E/PO, that allows me less time to do the stuff that can improve my reputation.
> (Research scientist)

> There are some people here that are so research-oriented; they really look down their noses at the E/PO program.
> (Discipline scientist)

> Every step they take toward making the education activities more visible, the more they run the chance of alienating themselves from the rest of the community of scientists.
> (Education Council member)

Because academic and corporate environments demand that scientists produce research results, many scientists in our sample report that the time they put into education is detrimental to their careers.

> We have young scientists at [the university], and it can actually hurt them. When it comes time for them to look for a new job, they want to see the papers that you published. (Mission scientist)

> If your name's not out there, you just drop off the radar. (Research scientist)

To combat the cultural bias against education, the OSS E/PO Program has begun to develop ways to identify and reward scientists who have created educational resources.

Workshops for Scientists

Each year for the past seven years, NASA's Education Division and the Office of Space Science have supported a four-day workshop for scientists, engineers, and E/PO leads. At the workshop, scientists have the opportunity to meet with teachers, both during presentations given by teachers at the workshop, and on school visits where scientists may have the opportunity to observe classes. Scientists also work with hands-on classroom resources and discuss how such materials support inquiry-based curriculum. The workshop content delves into the needs of classroom teachers and school systems, the national science standards, and the nature of science curriculum development.

Scientists report that the workshop has increased their awareness of the complexity of E/PO and that it made explicit the different ways they themselves can become involved. Scientists teaching at universities report that they have altered their own classroom presentations as a result of the workshop: using more hands-on activities in classes; having students break into small groups to discuss ideas; investigating student thought processes; and leveraging the Internet more effectively.

> It's a matter of both opportunities and rewards. We've been good at providing opportunities; rewards are critical for long-term success. NASA can provide rewards in terms of recognition. There's also the problem of institutional awards. There's been disapproval for scientists doing E/PO. We can't necessarily change the institutional cultures, but we can try to make sure there are NASA rewards.(Education Council member)

To facilitate the identification of significant E/PO activity, OSS has created its own Tracking and Reporting system (T and R). The T and R system was designed to augment and be compatible with the NASA-wide EDCATS[14] system. It provides data for a variety of mechanisms for tracking OSS E/PO activities, including the Annual Report, the Space Science Education Resource Directory (SSERD), and internal and external newsletters. These publications serve to provide both recognition to those individuals who have been instrumental in the creation of space science E/PO and a means for the OSS E/PO Program to communicate its accomplishments to the scientific and educational communities, addressing a serious need. In our data collection, we encountered many individuals across all populations who were aware of significant space science E/PO activity, but were unaware of its genesis. Publications such as the Annual Report and the newsletters may help address the problem of ambiguity in attribution for E/PO activity.

THE EDUCATIONAL COMMUNITY

Educators face a number of challenges when they try to incorporate OSS materials into their classrooms. First, some materials are expensive or require expensive computer systems to support them; limited school budgets may not allow for the use of these materials. Second, time is a major factor. Teachers have limited time in the classroom and limited time for professional development. Time pressure in the classroom is magnified by the need to cover materials in national, state, and/or district standards. Teachers also face challenges in finding time for professional development (PD), which is needed because many teachers, especially at the elementary or middle school level, have had limited training in science.

The data in this section come directly from teachers we interviewed as part of this evaluation—teachers who have had some contact with OSS E/PO. These teachers express concerns similar to those we have heard in hundreds (and possibly thousands) of interviews with K–12 teachers over the past decade. Teachers across the nation face challenges that grow from the complexity of the culture of education. Appendix B elaborates on the historic and current complexity of American education.

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[14] NASA Education Division Computer-Aided Tracking System

Resource Limitations

Elementary and middle school teachers are constrained by severely limited budgets. Teachers have little input into funding decisions, which are driven by the demands of local, state, and federal institutions. Furthermore, teachers have limited input in the selection of the curriculum in their classrooms. Many schools provide teachers with no materials beyond district-mandated textbooks and associated materials. Given the financial constraints faced by most teachers, even small amounts of money can make a large difference. While some districts provide support to teachers who seek out additional resources to engage and stimulate their students, many K–12 teachers report spending their own personal money to provide materials and resources they consider vital to their teaching.

> As a teacher, the school gives me $100 for the year, including pencils and paper. That's a communication problem between teachers and NASA. Someone at [a NASA center] said, "Boy, you teachers just want everything for free." I don't think they realize that everything we buy comes out of our own pockets.(Elementary school teacher)

Budget limitations can pose a challenge, even when material is low-cost or free on the Internet, because classrooms may not be equipped with the necessary technology.

> There were problems in my first lesson; it's JavaScript, illustration-heavy. It taxed the capacity of the computers. (Middle school teacher)

> I talked to teachers and they say, "I can get resources, but I don't have the computers to access them. I get a computer in the library, or one for forty kids." They'll pay to bring a teacher to a workshop to learn how to use the CD-ROM, but won't pay for computers so the teachers can actually use the CD-ROM.(Mission scientist)

> We have a wide range of computers and not all of our computers can use the JavaScript. (High school teacher)

While the Internet can provide quality materials to many classrooms and science museums at low cost, it is important to realize that they do not meet the needs of *all* educators or students. In particular, schools and science centers in areas that have high underserved/underutilized (U/U) populations are less likely to have full connectivity. Access limitations have a profound effect on the ability of educators to utilize OSS E/PO resources.

Standards and High Stakes Tests

Increasingly, the time to be spent on each subject area for every grade is being dictated by state requirements. State tests assume that a certain prescribed amount of time is required to master each content area and to perform well on the tests. Teachers report that many science topics require more time than allotted by the curriculum, but they are conflicted about adjusting the schedule. They express concern that spending time developing a single topic, or using supplemental materials, will prevent them from teaching the breadth of content covered by the test.

> There are time constraints and curricular constraints imposed by the standards. (Middle school teacher)

> Assessment drives your practice in a way; it affects what you want your kids to know and be able to do. (Elementary school teacher)

> Then there's the issues faced by teachers facing high-stakes tests. When one's performance is evaluated on these tests, it's difficult to get anything into the classroom that isn't part of that. (Education partner)

At the elementary school level, the emphasis on literacy and numeracy is increasing, largely due to the tests. This has led to an increase in class time devoted to those subjects, with subsequent reductions in time for other subjects.

> At second grade, we're being told to drop the science to teach reading and math.(Elementary school teacher)

At middle schools and high schools, science curriculum is dominated by biology and chemistry, with some physics at the upper levels, leaving little room for space science during the teaching day.

> I know within my own building, because earth and space science don't get a lot of attention, material from NASA just kind of gets ignored. (Middle school admi

Even in those areas where space science is explicitly mentioned in the state or district standards, there is often confusion about what students need to know and the best way to impart that information.

> My district has said they're not going to do anything until the state gets clear on what we have to teach our students. (High school teacher)

Given the confusion around standards, educators benefit from explicit linkages between standards and individual products. Because space science is a very small part of the national science standards, relating E/PO materials to standards across the science curriculum (and beyond, to math, technology, and other standards), makes it easier for teachers to utilize resources in their classrooms.

> We could get it in more easily if it could be tied more directly to standards. We need to see where it *can* fit in terms of bio., physics, and chemistry.
>
> (Educational administrator)

> My suggestion to NASA: They should align this material with state or national standards. Then teachers will see that connection and see that this is quality time on instruction.
>
> (Former high school teacher)

A couple of the Forums have begun the process of standards alignment through the creation of standards quilts, electronic databases linking OSS E/PO resources to the national standards for each grade level. Despite the quilts, some educators say that OSS materials are *not* standards-aligned. They believe that OSS needs to make a greater effort to create materials that truly meet their needs, in terms of providing resources that will allow them to teach their students what they need to know for the tests, in a way that is straightforward and accessible.

> I've been looking at NASA products that are supposed to address this standard or that standard, and they hit pretty broad of the mark.
>
> (Educational administrator)

> I believe that the issue of access to resources has to be part of a larger plan. You're trying to get us to use your stuff, but maybe we don't like your stuff. Look at what we need, and see if your stuff needs to be changed in some way.
>
> (Educational administrator)

The Midwest Space Science Education Initiative

This initiative grew out of a weekend-long retreat that included scientists, educators, education administrators, and SN staff. During the retreat, scientists shared their research with educators. Educators told scientists and SN staff about the challenges they face and explored ways that NASA and OSS can help meet these challenges. As a result of these discussions, several opportunities have been created for teachers in the Midwest to partner directly with individual scientists. These collaborations are intended to lead to the development of educational materials based on the research of the scientists.

The Midwest Space Science Initiative is a step in the development of relationships between the SN and teachers in the Midwest. In 1999, a Chicago Teachers' Advisory (CTA) was formed. This advisory group met quarterly and provided both a venue for teachers to get quality space science information, and a forum through which they could communicate about their needs. The CTA influenced the Space Science for Illinois Teachers (SSIT) program, which in turn influenced the development of the Midwest Initiative. In all cases, the educators involved had an active role in determining the structure of the partnerships, the organization, and the meetings.

Teachers' Need for Professional Development

Research in education reform in the last decade has identified professional development (PD) as a high priority for improving student learning, especially in the areas of mathematics and science, where K–8 teachers are most likely to be underprepared. Teachers, however experienced, need continuing PD to deepen their knowledge base and strengthen their efficacy in teaching for understanding. Many elementary and middle school teachers feel overwhelmed, as they are not trained in basic science, let alone physics or space science. They are subject to the same misconceptions as the rest of the world, including those fostered by the media. While these realizations are well supported by many at the local and state levels, access to quality PD is limited.

There are a number of factors that limit access to PD, including the supply and training of substitute teachers, limited funds to provide classroom coverage while teachers are participating in PD, and the cost of implementing PD for all teachers at all levels of need. Funding restrictions may limit leveraging of PD to having trained teachers mentor or coach their district colleagues, often without compensation. It is common for a district contract to prohibit teachers from providing PD outside of their district during the workweek. In addition, in many content areas the need for high quality training is greater than the supply of qualified professional developers. One local strategy used by some schools attempting to maximize the benefit of teacher PD is to have teachers who have attended workshops share their knowledge with colleagues.

> I've shared with maybe 50 teachers in my school. Maybe 200 people overall. You just kind of fall into explaining. You come in contact with people and you tell them something exciting. (Elementary school teacher)

Because teachers are not always able to access PD, space science resources themselves need to provide enough background material to provide the teacher with the confidence needed to teach the material. Background materials need to be accessible to teachers who have limited knowledge of space science and little time to become acquainted with new science education materials.

> Most teachers in school know the basics [reference to knowledge, skills], but they are out of touch with new thinking. Professional scientists are trained in subject matter, on the cutting edge; [they] can make this known. Teachers follow what is in the book. (E/PO staff member)

Teachers expect E/PO to be meaningful, useful, and relevant to their own curricular and pedagogic needs. E/PO should be based on the principles of quality curriculum and PD. To do otherwise is to ignore the importance of teacher's learning and teaching needs.

Space science can be a resource for education. The OSS E/PO Program can equip educators with high quality science content that has great interest to students and is frequently connected to exciting mission results. While data from missions are often not analyzed until well after mission completion, access to missions offers learners the opportunity to learn along with the science communities and witness (and even participate in) the development of new knowledge and understanding.

With few exceptions, *funding* for E/PO is related to specific NASA missions or research projects. However, space science *content* needs to be structured around concepts or themes that can be easily integrated into existing curricula. Mission information is interesting and important, but not sufficient to support student understanding. Teachers need to have the information coming from these missions or projects contexturalized within the larger set of space science ideas. Such approaches will provide both teachers and students an opportunity to appreciate the meaning and value of the findings.

SUNBEAMS

Students United with NASA Becoming Enthusiastic About Math and Science (SUNBEAMS) is a program in the Washington, DC area involving teacher professional development and student enhancement. Urban teachers spend five weeks at a NASA center during the summer where they work closely with a scientist-mentor. During the school year, the mentor visits the teacher's classroom, and the entire class spends a full week (all day, every school day) at a NASA center, working with the mentor and getting to meet a variety of other staff members.

SUNBEAMS was developed in 1998 under the auspices of a solar scientist and a staff member from Code FE. A former DC schoolteacher is currently helping administer the program, which has adapted to fit the needs of the teachers and scientists involved. SUNBEAMS is supported by funds from several missions related to solar science.

IMPLICATIONS FOR COMMUNITY BUILDING

The OSS E/PO Program has been striving to facilitate relationships between scientists, educators, and resource developers who can work together to create educational resources. Scientists should not, and need not, be solely responsible for the creation of E/PO resources. Rather, their expertise in science content is best utilized by working with others who have expertise in education.

> We can't expect the scientists to develop the materials. We have to know how to appreciate their culture and learn how to adapt it into our approach of scientific inquiry. (Education partner)

Some scientists desire direct involvement with the development of their research into E/PO resources. Many of these scientists have already worked on E/PO in some way.

Many scientists that we spoke with told us that they struggle with presenting their data in a way that will be approachable by someone who has neither their background understanding nor their passion for the specifics of the mission.

> [It has been challenging] to make something that looks straightforward to a scientist, who does it everyday, look straightforward to someone who'll do it only once. (Research scientist)

> The challenge to the scientific community is to translate our work to the public. What spin do you have to put on it to get people to listen and pay attention(Research scientist)

Scientists benefit from learning directly about the challenges faced by educators, and by working closely with those who are expert in the field of education. The more they learn about the educational community, the more effectively they will be able to transform their own research into E/PO resources that will be useful to the audiences the OSS E/PO Program serves. At times, scientists and teachers work together, either by having scientists work in the classroom or by bringing teachers to NASA centers. By working together, scientists and educators have the opportunity to see each other's strengths, challenges, and motivations. This is the first step in developing the cultural competency necessary for successful collaboration.

> First you've got to get the scientists and the teachers in a room together and then you've got to get them to agree that one is not dumber than the other. (High school teacher)

> Teachers work closely with a partner at NASA. So closely that they become part of the research group. The myth that teachers couldn't do it has been dispelled. They really learn the excitement of science firsthand and internalize it.(Mission scientist)

> It's getting the two communities to understand their respective languages. They're coming from different worlds, and getting them to understand each other and each other's needs is a challenge. (E/PO lead)

To facilitate interactions between scientists and educators, the SN is currently planning a conference that will include a strong presence from the educational community, teachers, museum staff, and other end-users of the E/PO products that OSS produces. The conference is intended to provide an opportunity for scientists, educators, and E/PO developers to talk about the realities in which they operate, and to provide professional development for all participants.

The OSS E/PO Program has also encouraged scientists and educators to work together on specific projects. Such partnerships allow all parties to contribute expertise and provide an opportunity for the development of educational resources that are both scientifically and pedagogically sound. Partnerships between individuals act as role models for other scientists and educators. Spending time and energy developing individual relationships may function as a high-leverage change agent in the way scientists and educators relate to one another.

Not all scientists are motivated to make such a large investment in learning about the educational community, but want to contribute to E/PO in other ways. The OSS E/PO Program has created options for such scientists.

> We want to point out to active researchers that there are a lot of opportunities where they don't have to take a lot of time and they can get involved in these types of activities. We want to ally them with other individuals or groups that are already doing education and outreach. (Professor/research scientist)

One suggestion being considered by the OSS E/PO Program is to provide limited funds for scientists who contribute time or knowledge to existing E/PO resources. Some scientists participate in existing educational projects, join existing programs, or speak at already planned events or exhibits. Encouraging such activities provides opportunities for scientists to participate in E/PO without taking too much time or energy away from their research.

> Some PIs would like to do E/PO but don't have the time or knowledge to put together a proposal. But you could ask if people are willing to help in E/PO activities that are done on a national scale. (Discipline scientist)

Another contribution scientists can make which requires a smaller time commitment is reviewing E/PO resources. Because scientists are knowledgeable about current research, they are in a strong position to assess the accuracy of materials that have been developed by educators. E/PO developers who have received such input from scientists report that they have found it helpful.

> We invited scientists and we presented the presentation. They were great; they constructively ripped it to shreds. It was good, because it started out being from an educator's perspective. We took all their suggestions, wrote notes, went through multiple science and education reviews until we got each side happy. (Education Council member)

These types of relatively low involvement activities can serve as an entry to E/PO for many scientists who have traditionally avoided it. Several scientists are already acting in these capacities. If OSS can provide modest funding for these activities, it may motivate more scientists to contribute to E/PO.

One large challenge is combating scientists' belief that they must make significant investment in learning about education in order to make meaningful contributions. Scientists need assurance that working in education does not require them to become experts.

> One of the difficulties is you need to learn a whole new set of rules, jargon, new way of doing things. We're not sure that it's a good use of our time, because it's not our field of expertise. (Mission scientist)

Many scientists express frustration with their limited understanding of the national science standards and educational pedagogy. Data indicate that although many scientists would like to create successful E/PO products, they erroneously believe that their limited knowledge and experience prevents them from doing so. The OSS E/PO Program can support these scientists by clarifying the roles they are expected to play and by coordinating partnerships with individuals and organizations that have the pedagogical expertise needed to create quality E/PO resources.

> There's a sort of mismatch between our skills and our training and what we're being asked to do. We can learn some but not necessarily to the "professional" level where it can be handed off. It takes so much time to learn it; it may not be a useful expenditure of our time. (Research scientist)

> If you want to create curriculum, it needs to be aligned with national standards. Scientists don't necessarily have time to learn all that, so there are better ways to make use of their contributions. (Education Council member)

Our data indicate that some scientists struggle with being in a non-expert role. Scientists are accustomed to being in control of their own data. As noted earlier (page 9), science is competitive and many researchers guard their findings jealously. These researchers report that it can be challenging for them to hand research findings to a non-scientist, who will shape, restructure, and simplify it.

> The whole point of getting a Ph.D. is to have some knowledge that makes you an expert—you know something nobody else knows—it's what makes a scientist valuable. Creating educational resources that are accessible to everyone is directly counter to that. (Research scientist)

> Sometimes that is tough on the scientist community because they cringe at the things you have to do to make it understandable and interesting. (Research scientist)

Some of the scientists we spoke with voiced concern over the *quality* of the E/PO resources utilizing their findings. They expressed a lack of confidence in E/PO developers' ability to create accurate and appropriate materials. Thus, scientists feel obligated to supervise the entire production cycle and have difficulty limiting the time they devote to E/PO activities.

> You can't just pick up a book and learn about the sun. You need someone with a real understanding. We had to write the whole damned thing. (Mission PI)

> People [who are developing resources] don't understand the science, and when they try to simplify the language, they use words that change the meaning.(Mission scientist)

One challenge to having scientists and educators work together is that some scientists interpret the underpreparedness of some teachers as an indication that teachers are unable to understand the complexities of space science. Scientists sometimes communicate their low expectations for teachers in ways that overwhelm the educators and make meaningful communication difficult.

> Many teachers I deal with have backgrounds in music or English and they can't even describe what a day is. (Research scientist)

> I don't know your background, so I'll assume you need to know everything. (Research scientist addressing a g

> Scientists have an attitude like teachers don't know anything. I don't need more people telling me I'm stupid. (Middle school teacher)

By allowing scientists and educators to come together and hear about the environments under which each of them operate, the OSS E/PO Program plays an important role in establishing "strong and lasting partnerships between the space science and education communities."[15] The Program is helping to develop much-needed opportunities for interaction between the two communities.

[15] *The Space Science Enterprise Strategic Plan*, 2000 (p. 23)

ADDRESSING THE GOALS OF THE OSS E/PO PROGRAM

The 1995 Implementation Plan presented four goals of the OSS E/PO Program.[16] While these goals presented a vision of the OSS E/PO mission, many members of the Program found their language confusing and non-memorable.[17] The E/PO administration responded to this confusion by simplifying the language and expressing the mission as three goals, which are presented in the 2000 Strategic Plan [18] as follows:

- To share the excitement of space science discoveries with the public
- To enhance the quality of science, mathematics, and technology education, particularly at the pre-college level
- To help create our 21st century scientific and technical workforce

The OSS E/PO Program is making significant progress toward all three of these goals and there have been many successes. Some of the more important activities of the OSS E/PO Program are outlined below. They are discussed more fully later in the report.

The OSS E/PO Program has worked with museums and science centers to make its findings available to those who wish to learn about them. Many of the exhibits that the Program has contributed to have been recognized as exemplary. The OSS E/PO Program is also providing access to space science information through community groups, libraries, and places such as malls, where they are able to reach audiences beyond museum visitors and students. OSS' museum-related work is explored more fully on page 26.

Lay science enthusiasts can also learn about space science at home via the Internet. The OSS E/PO Program has utilized the World Wide Web to share knowledge with net-surfers at home, in school, at libraries, and at other connected venues. While the response to the information available on the OSS Web pages has been positive, some users find the pages difficult to navigate. These navigation difficulties are frustrating to users, many of whom express a great hunger for space science information. Providing a method for users

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16 *Implementing the Office of Space Science Education/Public Outreach Strategy*, 1996, p. 3.

17 See PERG's June 2000 Evaluation report, p. 13 for a discussion of this issue.

18 *The Space Science Enterprise Strategic Plan*, 2000 (p. 23)

of the Web pages to give feedback would allow the OSS E/PO Program to meet their needs more effectively. Internet resources are discussed more fully on pages 28 and 32.

One area of focus for the SN has been the development of a Space Science Education Resource Directory (SSERD), which was conceived as a central database for OSS E/PO resources. The SSERD was made available to the public in October 2000. The response to the directory by the audiences it is intended to serve has generally been positive. One limitation to the directory is that it currently lists only electronic resources. The limitation is related to the difficulty of producing and distributing non-electronic resources; demand for products often exceeds the capabilities of the system to provide copies. The OSS E/PO Program was concerned that it would not be able to distribute a sufficient quantity of “hard-copy” products (posters, workbooks, lithograph sets, etc.) if the SSERD increased educators’ awareness of, and desire for, the products. The OSS E/PO Program is exploring options for the duplication and distribution of hard-copy products. In the meantime, the SSERD has increased awareness of Internet-accessible resources that can be distributed at low cost, provided the end-user has the electronic capability. The SSERD is discussed in greater detail on page 30.

The OSS E/PO Program has also made significant movement toward reaching audiences that have traditionally been underserved by NASA educational products. White males have long dominated space science and there has been little emphasis placed on reaching a diverse population. OSS collaborated with NASA’s Code EU (The Minority University Research and Education Division) to create the Minority University Education and Research Partnership in Space Science Initiative (also known as the Minority Initiative, or MI). The MI supports the development of space science academic programs at minority institutions and the development of research collaborations between these institutions and mainstream space science institutions. The OSS E/PO Program has also begun to develop relationships with several minority professional science organizations. Furthermore, the Program has supported the development and distribution of materials designed to meet the needs of diverse audiences: materials printed in languages other than English; materials designed for students with disabilities; and materials appropriate for students in economically-disadvantaged rural or inner-city communities. In this way, OSS is working to share the excitement of space science, improve education, and build the 21st century workforce with *all* populations. The issue of increasing diversity is examined in detail starting on page 35.

The reader should bear in mind that this report focuses on implementation rather than impact. Thus, end-users of OSS E/PO products were not included as data sources. Data reflect the experience of educators and scientists, rather than students, museum visitors, and the general public. These individuals’ voices will be heard in the third evaluation report, which will examine the *impact* of OSS’s E/PO activities.

SHARING THE EXCITEMENT OF SPACE SCIENCE

Because it is publicly funded, space scientists believe that NASA has an obligation to make its findings available *and accessible* to the public.

> I think ultimately, since the public is paying for NASA, they need to feel good about it. (Mission scientist)

> There are a lot of Americans and a lot of kids who may never get to see what we see around here, and you sort of have a responsibility to let them look over your shoulder. We have an opportunity to share with them. We're standing on the shoulders of giants. You've been to the mountain and seen what's there—on the way back down, stop and share what you've seen. (E/PO lead)

The OSS E/PO Program has been successful in working with scientists and E/PO staff to create and share resources that tap into the public's interest in space science. They have disseminated resources in a number of ways.

Museums offer a unique opportunity to reach both K–12 students and the general public. While they serve schools, they also draw voluntary visitors from a variety of backgrounds. Museums and science centers have the freedom to go beyond national science standards, a freedom that is not always available to classroom teachers. Museum visitors are also relatively free of constraints. When visitors go to museums, they have complete control over their experience. In classrooms, the curriculum determines what the learner will learn. In a museum, the learner makes that decision for him- or herself. Consequently, museums are becoming ever more visitor-centered.

> Museum visitors are less structured, innately curious. They don't have the same type of barriers that teachers have including time, lack of support, lack of access to infrastructure. (Education Council member)

The OSS E/PO Program has developed strong collaborative relationships with a number of large museums. Because the SN is designed to reach out to a number of communities, staffing included several individuals with established ties to the museum community. Some new collaborations have been the result of fortuitous proximity. Museums that are located near institutions that are part of the SN were among the first to establish ties with the OSS E/PO Program. In addition, the OSS E/PO Program has proactively developed relationships with several museums that have benefited from congressional earmarks.

The OSS E/PO Program has also contributed to the development of a number of large-scale traveling exhibits, including *The Space Weather Center*, *Hubble Space Telescope: New Views of the Universe*, and *MarsQuest.* Each of these exhibits is a result of collaboration between scientists, OSS E/PO personnel, and educators from outside OSS. By working together, these individuals were able to contribute expertise from different areas to create materials that are scientifically accurate, pedagogically sound, and exciting to visitors.

> For me and the content development, it's made all the difference in terms of the richness of the content we have access to. There's no substitute for talking to scientists about the things they're passionate about. It's interesting that you take this very intellectual scientist and scratch the surface and find this passion about what they do. (Museum administrator)

> These exhibitions are so complex to put together. There's first, the conceptual design. We involve many scientists at this level. There's an important process of team formation that goes on. Then working with designers, artists, and computer programmers is quite complex. (E/PO lead)

While large-scale exhibits such as these are effective ways to draw people into space science (and provide opportunities for scientists and educators to work together), smaller museums and science centers offer access to other populations.

Many smaller museums serve minority populations. These populations have traditionally been underserved by NASA resources. Thanks to active participation in organizations such as the Great Lakes Planetary Association (GLPA), there is a growing network of small to midsize museums around the country that benefit from the work of OSS E/PO.

> There are about 1,500 planetariums in the US. They're on shoestring budgets and they have great ideas for neat projects. They have up to 40,000 visitors a year, and they are lacking just a few hundred dollars to carry these projects out. (Education Council member)

Cosmic Questions: Our Place in Space and Time

SN staff members are currently developing this traveling museum exhibit, with space scientists confirming the accuracy of the content. The goal of the exhibit is to provide challenging intellectual content about the universe to the public. Visitors will engage in a series of interactive exhibits about the tools and means scientists use to conduct their research, ponder some current ideas and theories about the origins and nature of the universe, and use those experiences to construct their own understanding and generate their own questions.

Over 100 scientists from across the country have contributed to the content and development of the exhibit, attending small group meetings and workshops to hear about the exhibit ideas and contribute their own advice and science expertise. Several scientists are completing video interviews, segments of which will appear in exhibit components. The Cosmic Questions Advisory Board includes members of several national science centers and planetaria, and space science experts in the themes related to the exhibit. Scientists are pleased to participate and recognize the value of the exhibit. They continue to be helpful and responsive and are excited to see the final exhibit.

Several exhibits (such as the *Space Weather Center)* have been designed in such a way as to be usable by museums with limited space and technological capability. The *Hubble* exhibit comprises both a large and a small format, so that a museum can use the version that is most appropriate, given its resources.

> You can create an initiative where a big, well-known museum partners with smaller science museums that are not in competition with them. I can think of a number of initiatives where large and small museums could partner to create a vehicle for scientists and educators to work together. Often the smaller museums take stuff from the larger ones. (Education Council member)

Beyond the smaller exhibits discussed above, many smaller museums and science centers are eager for images and animations from NASA missions which museum staff can use to create or augment exhibits appropriate for its audience and the physical realities of the museum space.

> As a medium, animations and video clips are the most motivating and useful.(Small planetarium staff member)

> Slides are good things to send to museums because they actually show it. We can also send them news footage from old shows; many museums simply want access to stuff that already exists. (Education Council member)

> We take the raw input and interpret it in a way that makes it accessible. (Large planetarium staff member)

Because the educational staff at the museum takes responsibility for providing a context for the images, scientists need only concern themselves with content. This relieves them of some of the pressure they report when they are responsible for finished products.

For those who do not have the time, opportunity, or desire to visit museums, OSS Web pages provide access to a wealth of space science information. The science and Internet communities have recognized several OSS sites as exemplary. These include *Gateway to the Universe of X-Ray Astronomy* (http://www.chandra.harvard.edu), the *Solar Max 2000* Web site (http://sunearth.gsfc.nasa.gov), and *The Cosmic and Heliospheric Learning Center* (http://helios.gsfc.nasa.gov). These pages have drawn positive response, and have been helpful to many members of the educational community (see page 32).

Some challenges remain. Users often find it difficult to find the information or images they are seeking. Data indicate that linkages between OSS pages (spacescience.nasa.gov) and the main NASA pages (www.nasa.gov) are not always intuitive to follow, and the search functions are often difficult to use.

> You know how it is on the Internet. Once you get there, you will never find it again. (Elementary school teacher)

> We tried to get a direct link. It makes me crazy on NASA Web pages. I just want to find an activity about the moon and can't find it. It makes me crazy.
> (Education Council member)

> I've looked at the OSS Web sites. They aren't that useful because there is so much there and it's not that well organized. I usually just use a search engine to find what I need.
> (E/PO staff member)

While the above comments come from individuals who are working in science education, it is likely that those who use the sites casually face similar challenges in finding the material they want. Because few of the pages provide any type of feedback form, it is difficult to assess how users experience them.

Reliance on the Internet also provides unequal access to various constituent audiences. NASA's assumptions about equity belie the documented inequity that continues to characterize the technology experiences of students nationally. Web-based materials fail to meet the needs of those communities most underserved by NASA education.

On the non-electronic plane, OSS has begun reaching out to the public in unexpected ways and places. Solar System Ambassadors, volunteers with an interest in solar system science, bring science to such places as Rotary Clubs, libraries, museums, planetariums, "star parties," and mall displays.

Together, educators and space science E/PO staff are creating a broader, truly accessible network of resources that does not depend solely on proximity to space science organizations or the Web. Rather, it makes space science resources available through after-school programs; organizations such as the Girl and Boy Scouts of America and the 4-H club; and at non-school venues, such as malls and public parks. Programs such as *Explore!* and *Space Place* allow

Project Explore!

Explore! is a cooperative project engaging libraries as partners in providing community access to NASA educational resources. A major component of Explore! is a series of hands-on "Fun with Science" activities, developed by OSS E/PO and library staff, with OSS scientists providing content support. Used in either after-school or summer library programs, the activities are targeted at the sometimes difficult to engage preteen population (primarily ages 9-12). Each space science activity module contains background information, scientific principles, and follow-up questions with recommended videos, books, and Internet sites as well as the fun hands-on activity. Librarians report that the program has been successful in rekindling interest among preteen and teenage patrons, and that it has elicited strong interest from parents. High demand from children's librarians has prompted the Explore! team to develop hands-on activities for the K–3rd grade audience to accompany each "Fun with Science" activity, which now gives Explore! an opportunity to serve a broad range of American youth.

The program was originally implemented in Louisiana, is currently being developed in Texas, and will be extended to other states as resources and collaborations are accessible. Plans call for the libraries to also serve as a national distribution network for NASA public materials.

OSS to reach students in informal education venues, such as libraries, museums, zoos, and aquariums. Staff at venues utilizing these programs report that they are effective in getting young people excited about science.

> Before they wouldn't have checked out any books. Now they are checking out books on the development of rockets. And they study about comets at school. But they weren't interested in that beforehand. (Librarian working v

By making space science information available in a variety of formats, through a variety of media, the OSS E/PO Program allows the public to take advantage of the knowledge that is being delivered by the missions and research programs.

ENHANCING THE QUALITY OF EDUCATION

OSS contributes to the quality of formal K–12 education in a variety of ways. Many of the resources that share the excitement of space science also enhance the quality of education. In addition, the OSS E/PO Program contributes directly to the classroom experience by providing quality educational resources, many of which are catalogued in the new Space Science Education Directory (SSERD), and by providing professional development opportunities for teachers.

THE SPACE SCIENCE EDUCATION RESOURCE DIRECTORY

From the beginning, the OSS E/PO Program recognized a need for a centralized database where educators could find, and procure, a variety of OSS E/PO resources. The SSERD was created to meet this need.

> Once the Ecosystem organized itself, it needed a database of what was available. It's not enough to broker if you don't know what you're brokering. (OSS education partner)

The SSERD is the result of collaboration across a number of institutions within the SN, each of which has made a unique contribution to the development of the Directory. The administration of the OSS E/PO Program considers the SSERD to be one of the major achievements of the Program, and asserts that the Directory would not have been developed without the SN.

Various versions of the SSERD were piloted at national conferences, and changes were made based on teacher comments and recommendations. The SSERD was made available to the public in October 2000. The resource directory generated a great deal of interest among educators, and members of the OSS E/PO Program report that they have had much positive feedback about the Directory.

> We've seen an early surge of people checking it out. Over 400,000 page hits, over 4,000 searches, 184 user accounts set up. (Education Council member)

The Directory continues to be updated, and input from users is being collected and utilized for its improvement. The development of the Directory provides a good model for soliciting and listening to user input, which allows the OSS E/PO Program to develop resources that can meet the needs of its intended audiences.

At present, the catalog contains only electronic resources, a reaction to challenges related to the distribution of printed materials (see page 32). There was concern about including materials in the SSERD that might not be available to every user who wanted them.

> Our customers want to know how to get a hold of posters, lithos, etc. They're currently not in the Directory. That was a tactical decision on our part. We can't say "Here's a really great kit, but you can't have it." So for the first year, we decided to go just with Web sites, PDF[19] files and so forth. We don't want to frustrate the customer. (Education Council member)

While focusing on electronic resources does avoid the problem of distribution, it omits many useful resources. This is frustrating both to teachers (who can't find the resources they need) and to resource developers (whose work is not reflected in the catalog). The OSS E/PO Program is actively looking for solutions to the distribution challenges (see p. 32). The Directory's entry system was recently revised to allow developers to enter non-electronic resources. At present, once these resources are entered, the listings are not made accessible to educators using the directory. They are being included in the database so that they can be made readily available once the distribution issue is addressed.

PRODUCTION AND DISTRIBUTION OF RESOURCES

Under Code FE, a national distribution system for approved educational products has been in place, consisting of a national network of Education Resource Centers (ERCs), Space Link for electronic products, and CORE[20] for the distribution of media such as videotapes and CD-ROMs.

The ERCs function as distribution points for many resources. Each state has its own ERC, which is responsible for disseminating resources and providing support to teachers in using these resources. Teachers in our sample indicate that NASA ERCs are often under-supplied and inaccessible to educators in isolated areas.

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[19] Portable Document Format, a non-platform-specific format. While this type of file is readable on all computers, the documents themselves can be quite large and time-consuming to download, especially on older machines.

[20] Central Operation of Resources for Educators, a distribution system for multi-media resources.

> The problem is, there's not a NASA store on every corner. If you want NASA materials, you have to plan months in advance, and jump thorough hoops and hope you get the stuff. (Elementary school teacher)

In addition to being disseminated through the ERCs, many NASA and OSS educational materials are distributed at national or regional conferences. This leads to haphazard distribution, with materials going to those who are present, rather than those who have the most use for them.

> A lot of my frustration has been getting appropriate materials. It used to be easier, but within the past five years, it has been very difficult. If you get to go to NSTA conventions, though, NASA has big booths and you can get all sorts of stuff, but at ERCs, the stuff isn't there. (High school teacher)

> It happens by chance. For example, a really great pamphlet is developed. It's really needed. That pamphlet is produced in 5,000 copies, distributed at a national meeting. And if a teacher is there, they get the resource; if they aren't, they don't. (Science education developer)

As NASA creates more and better educational products, the demand for products increases, and there is not always sufficient capability to meet the demand. No matter what mechanisms are in place for distributing materials, there is a problem if resources cannot be produced in sufficient quantity to meet demand.

> I'm not sure what the final solution will be. Are we going to be able to produce enough hard-copy products? It can be risky and difficult. There is no budget for distribution and production. (Education Council member)

> Distribution is a problem. The materials supply issue is still unsolved. [Products] won't print it themselves. (E/PO lead)

As noted above, the OSS E/PO Program has been exploring the related issues of production and dissemination and has tried a variety of strategies to help with distribution. At present, OSS is working with NASA CORE to develop methods for distributing CD-ROMs and other audiovisual resources. OSS is also exploring the possibility of working with commercial partners for the production and distribution of paper resources, such as posters and lithograph sets.

Because of the difficulties related to distribution of "hard-copy" materials, OSS has placed an emphasis on electronic E/PO resources. Through the Internet, OSS can potentially reach a wide audience at minimal cost.

Electronic means of distribution have a strong appeal. They present minimum cost to NASA and provide access to a potentially unlimited audience. There is hope that electronic access will grow as computer capabilities expand and as more schools get wide-band access and a computer and printer for each teacher. Furthermore, many students (especially white students in economically advantaged areas) are growing up with computers and are comfortable using them.

> The kids really like the NASA home page. They managed it by themselves. Kids are very computer-literate. (Librarian)

> I use them [NASA Web sites] for myself, and when I do a workshop with students or teachers I hand out a list of the ones that I felt were most useful for me as a resource. I know that students and teachers go to those. (E/PO staff member)

Teachers who have Internet access find the NASA pages useful. They believe that NASA scientists are involved with the development (or at least the review) of the material. This gives them confidence that the information they get from the pages will be accurate and appropriate.

> With the NASA sites, we feel reasonably sure that the science is accurate, which isn't necessarily true at other sites. (High school teacher)

While on-line materials are useful to many, there are challenges. As noted in the section on public use of OSS Web pages (page 28), many users find the pages difficult to navigate. A more serious problem for schools is that educators in poor rural or inner-city communities typically have limited access to computers and the Internet. The high-tech, on-line materials that OSS creates do not necessarily meet the needs of those without access to high-speed Internet connections. This is particularly problematic in U/U communities.

> The Internet doesn't work in my community. You need that personal touch. Science is viewed as an aberration. It's a fearful entity in the black community. You need someone to generate the motivational impulse. (Minority scientist)

Amazing Space

Beginning in 1996 and continuing for several summers, ten teachers spent part of the summer at the Space Telescope Science Institute (STScI), working with scientists to create a Web page of classroom activities and information based on data from the Hubble Space Telescope. The resulting Web page has a variety of classroom activities for classrooms ranging K–12, each with supporting pages for the teachers. Activities on the Amazing Space Web page have been piloted at several teacher conferences.

The page has won several awards, and is referenced on a variety of educational Web pages maintained by organizations beyond NASA. Several states have included the page in their database of appropriate materials to meet their state standards. In addition, a variety of educational pages link to the Amazing

District educators report that even in wealthier districts, there is not unlimited access to computers. Because scientists generally have access to state-of-the-art technology, they are often unaware of the challenges facing schools; this is another manifestation of the cultural divide between scientists and educators. Every teacher needs to be trained, all students need to be trained, and all classrooms and schools have to have updated hardware and software to freely take advantage of space science resources.

> I worry about priorities, because teachers don't have real access to the Web. (E/PO lead)

> I talked to teachers, and they say, "I can get resources, but I don't have the computers to access them."
> (Mission scientist)

Solar System Educators

The Solar System Educators Program was created to share space science educational resources with educators across the country. These resources are developed by OSS E/PO staff and professional curriculum developers from data derived from a variety of OSS solar system missions.

Solar System Educators are master teachers who attend a four-day institute at a NASA center where they learn about space science and are familiarized with OSS E/PO materials. Each Solar System Educator has the responsibility to train an additional 100 educators, who then can utilize this information in their own institutions and regions. Solar System Educators share information and experiences with each other via e-mail and personal visits, creating a powerful support network amongst themselves.

These educators form a network whose purpose is to disseminate information and NASA resources nationally.

Even if teachers have access to the Internet, it is difficult and time-consuming for them to navigate the image-rich NASA Web pages and to download large PDF files. Many educators indicate that an on-line catalog is not as useful as a direct mailing (either snail or e-mail) about a new product.

> A lot of what I come across will be related to e-mail press releases. I don't have time to browse casually.
> (Small planetarium staff member)

Taken together, these data indicate that having the information available on the Internet is necessary *but not sufficient* to disseminate resources. Various institutions within the OSS E/PO Program have taken steps to develop CD-ROMs that include many of the PDF files that are available on line. This takes advantage of the low cost of electronic products while avoiding the challenges teachers face getting the materials on line.

PROFESSIONAL DEVELOPMENT

Resources are most effective when the teachers using them understand and appreciate the science that went into their development. As noted earlier (page 18), many teachers are underprepared to teach space science. Several of the teachers we spoke with had been involved in workshops at various

NASA centers. They spoke highly of the workshops, and indicated that they gave them insight into space science beyond what they could learn in a book.

> It's one thing to talk about something you've read, and another to have a firsthand connection. (Middle school teacher)

Some teachers receive professional development in their own classrooms, in the form of visiting scientists. While not all scientists have the time or motivation to visit classrooms, those who do can have a strong positive effect on the teacher and the class.

> It's helpful as a pilot, to have them "hold my hand." Having access to the scientists would help teachers who are reluctant or scared to introduce a new unit or new material to their curriculum. It would also help an adventuresome teacher to improve the adaptation of new material. (Middle school teacher)

As noted on page 22, having teachers work with scientists can also help both parties gain insight into each other's situation. Teachers who work directly with scientists report that they develop a better insight into the scientific process and can share their new understanding with their students. Scientists who work directly with teachers report that they have a fuller knowledge of the needs and challenges of the classroom. These teacher-scientist interactions provide professional development for members of both communities.

HELPING CREATE THE 21ST CENTURY WORKFORCE

The OSS E/PO Program is helping create the 21st century workforce by reaching out to all parts of the 21st century population. The Program has been proactive in reaching out to populations that have traditionally been underserved by space science education.

> One of these days, some of these minorities are going to be a majority, and how are we going to maintain our technology base if we don't get them interested in technical fields? We like to think that at NASA we have what's needed to attract them to technology. (Discipline scientist)

> I am extremely impressed with what [the management of the OSS E/PO Program] is doing, especially in relation to minorities. I think it began when [the administrative head of the OSS E/PO Program] began visiting minority institutions to see what's needed to make it work. (Minority scientist)

The most significant step OSS has taken to reach out to minority communities was the development of the Minority University Education and Research Partnership in Space Science Initiative (referred to as the Minority Initiative or MI) in collaboration with NASA's Office of Equal Opportunity Programs (Code EU). OSS and Code EU issued the NRA soliciting proposals in January 2000. The goal of the MI is the enhancement of minority college and university involvement in space science. One important strategy is the fostering of links among minority institutions, mainstream science research institutions, and OSS.

> It's a separate solicitation for minority institutions to get involved. This is such an important thing. We need to get more minorities involved in the sciences. We need to encourage people who have good people to get involved.(Discipline scientist)

Sixty proposals were received in response to the MI and fifteen were funded. The funded projects include development of new space science degree programs, establishment of new space science faculty positions, and university-centered E/PO programs serving K–12 minority populations. According to the administration of the OSS E/PO Program, the MI represents an entirely new area of growth for NASA, and represents a significant accomplishment.[21]

> By including minority students in educational programs, these children will then someday have a stake in what happens up there [at the observatory]. This grant will provide a new link . . . between the observatories and the community. (PI on a program funded by the MI)

The OSS E/PO Program is also building relationships with members of a variety of minority professional organizations. In May 2001, members of nine minority professional societies met with members of the OSS E/PO Program to address the goal of creating new research and education projects that will involve minority scientists and students.

> The general idea is that a couple of people from each of these organizations and a couple of people from each of the SN modules will meet. Hopefully, they will develop near-term projects that can be done in collaboration and lay out how such partnerships can be facilitated in the future. We need a mechanism for doing this in the future. (Education Council member)

The MI and the relationships with minority professional organizations both allow for the development of diverse relationships early in the development of research and educational projects. Incorporating diverse voices *from the beginning* of the development process is a priority. The strategy is to allow conversation among diverse communities during development, to ensure that needs will be met.

[21] Because of the timing of the MI and this report (and because this report focuses on implementation rather than impact), limited data were gathered about the MI from individuals associated with funded programs. We consider their reactions and voices to be of utmost importance, and they will be represented in the next report, covering the impact of the OSS E/PO Program.

> It doesn't work well if we wait until the project is completely defined to invite in new voices; they need to be involved from the beginning.
> (Education Council member)

> The best way to create projects that are appealing to minority scientists is to get minority scientists involved in development. I think [a minority scientist's] instincts about what will appeal to minority kids will be more accurate than lots of federally-funded studies. (Education Council member)

Partnerships with minority scientists, once developed, can help bring space science into those schools and communities serving U/U populations, and by extension, bring a more diverse population into the space science community. If scientists from diverse communities are present in the planning process, they can ensure that the resources are appropriate for other members of their community.

> It's important to start by listening carefully to advice of the communities we want to work with. It seems that it is important to have members of those communities from day one for the planning. The question is, how do we set up a way to make the right contacts that can lead to that kind of involvement?
> (Education Council member)

By developing opportunities for minority students, and helping them to become successful research scientists, OSS contributes to the creation of much-needed role models for the next generation. In addition, by working directly with minority scientists, educators, and students, members of the OSS E/PO Program can develop the cultural competency necessary to create resources that are appropriate for and appealing to U/U populations.

> I think there needs to be a very aggressive movement to work with teachers to identify the students who have an interest . . . We need to help teachers ID these kids and work with them as well. What surprises me is that teachers overlook the

An African American Experience —Connecting to Space Science

SN staff, in collaboration with the African American Museum in Cleveland, is developing a relatively small exhibit that will profile a range of African Americans working in space science and related fields. The exhibit will also provide general space science information from each of the four themes. The purpose of the exhibit is to share space science information with, and feature African American role models for, students who have traditionally been underserved by NASA resources. One copy of the exhibit will be permanently housed at the Cleveland African American Museum, while another will travel to small museums, primarily in U/U communities. The travelling exhibit consists of a three-panel display unit that can be configured in a variety of ways, allowing it to be utilized in a variety of physical spaces.

In addition to the two exhibits, there will be a companion set of posters, a videotape, and a resource guide. In addition to disseminating these in conjunction with the traveling exhibit, copies will be available separately. These will be distributed via several already existing NASA networks: SpacePlace, Space Grants, and Solar System Ambassadors and

> fact that these kids are very bright and only see them as problems. They're just trying to get through the material they're required to get through. (E/PO lead)

> If you have more fun science activities at U/U grade schools and high schools, you might get more people interested. (Discipline scientist)

Reaching out to diverse students is extremely important given the homogenous nature of the space science research community. Non-whites, females, and the differently-abled are underrepresented in research fields, especially the hard sciences. This problem is especially acute in space science, which is very much the domain of the white male.

> At HQ, there are *no* African Americans in space science. I don't think there are any Hispanics. There are probably four or five Asian Americans. At field centers, the situation is probably about the same. There are probably one or two Hispanics. I can't think of any African Americans who wear the NASA badge.(Education Council member)

Because there are so few minority scientists, their voices are not heard, and the needs of U/U groups are not understood. Consequently, the cultural divide between the space science community and the people it hopes to serve through the E/PO Program is especially large. Barriers are high, leading to lack of communication and lack of awareness. Because awareness is so low, many people working in space science believe that there is no problem with underrepresentation. Many of those who do acknowledge that there is a problem are not doing anything in particular to address the issue.

> There is no barrier for the Hispanics. (Professor/Research scientist)

> We didn't try to draw particular races or classes or anything. We just invited anyone to come. (Research scientist)

Among those who do recognize the problem, there is a tendency to avoid responsibility for the situation. Many blame the Office of Equal Opportunity Programs (Code E), a few blame NASA and scientific hiring practices, and an unsettling number blame the minority groups or minority institutions themselves.

> I've never had a minority student. There just don't seem to [be] that many in science. (Professor/Research scientist)

> Some minority institutions don't perceive themselves as trying to be first-class institutions; they perceive themselves as serving students who can't get into first-class institutions. That's why people have the image of HBCUs [Historically Black University or College] that they do. If they became first-class institutions, they'd have alumni that would have the resources to contribute.(NASA personnel)

Professors report that U/U students who are successful academically are more likely to focus on educational pathways that yield more immediate financial rewards.

> I think it's economic. The top black students are mostly taking business courses. We'd get more students if they could see the economic benefits, and if they were exposed throughout their career to math and science.
> (Professor/Researcher)

> For certain populations, you have to say, "Why would they want to do astronomy when they can have a bigger impact in their communities as doctors or lawyers and make more money?" (E/PO staff)

In addition to the general difficulty of breaking into a field dominated by white males, there are challenges specific to each minority group. For example, Chicano students often come from households where there is little support to pursue an academic science career.

> Frequently, the parents have not had the educational background to encourage their kids to seek higher education. They need mentoring and guidance. (E/PO staff member)

The lack of family support is also a challenge for some Native American students. In addition, OSS's approach to the structure and evolution of the universe does not coincide with traditional Native American beliefs about creation.

> People hundreds of thousands of years ago knew about science, and if it doesn't conform with the Western science model, it doesn't matter. It's invalidating of all native knowledge.
> (Native American research scientist)

While women are underrepresented in space science research, they are not as underrepresented as African Americans and Chicanos. Many female scientists report that they are motivated to share their excitement about science and act as role models for girls.

Multi-Sensory Space Science Kit

The Multi-Sensory space science kit was developed by a NASA space scientist for his own grandchildren. It contains multiple hands-on activities that engage students in open-ended explorations of fundamental science principles relating to flight and the solar system. The kit was originally designed to address the needs of students with learning disabilities. Members of the SN realized that the kit would be useful for students with physical, neurological, and perceptual disabilities as well.

In June 2001, SN and Code FE staff members hosted a workshop at which participants examined the multi-sensory kit contents, were made aware of the learning needs of the visually- and hearing-impaired, and developed guidelines for the creation of more universally accessible products for multiple populations of learners. Workshop participants included science teachers, educators for the deaf and blind, and representatives from each of the four Forums. Participants were very enthusiastic about the workshop. Educators for the deaf and blind were very excited about being involved in the effort to make space science products more accessible to their students. Forum members were enthusiastic about learning how to create space science products for diverse populations. The SN's advocacy of the kit has led to its adoption in Virginia and several other states.

> I'm a scientist, a doctor, and a mom. So that I serve [in] that [capacity] also. I don't do it as a feminist. My education came along because people took my education seriously. So for me it was equal opportunity. But it serves for opening up science. It is great to see girls involved. (Mission PI)

> I've gotten letters from sixth graders after I've visited the classrooms. Three girls said they wanted to be astronomers. I was thrilled. I know it can't go unnoticed that this looks like fun and here's a woman doing it. I hear all kinds of comments. I'm thrilled. (Research scientist)

OSS has recently begun to make strides toward making its materials accessible to the differently-abled. There have been several resources developed that use multi-sensory pathways. Not only are the multi-sensory resources useful for students with sensory deficits, they are also appropriate for students with different learning styles, or with attention-deficit disorders, who learn less effectively from purely visual stimuli. Recently a book has been developed for visually-impaired students containing not only visual, but also tactile images from the Hubble Space Telescope; this book has received a great deal of positive attention in the media, as it meets a need that few resources currently address.

IMPLICATIONS FOR ACHIEVING GOALS

The OSS E/PO Program has made many positive steps toward achieving the goals identified in the Strategic Plan. The following are areas where the OSS E/PO administration and staff can work to enhance movement toward the goals.

- Scientists have divergent opinions of their role in education. Continuing to create multiple opportunities for scientists to contribute to E/PO, and communicating these opportunities to them, will allow them to find ways to contribute that coincide with their personal attitudes, values, and achievement motivation. Providing appropriate professional development for scientists will help them appreciate the value of contributing to education and give them the skills they need to do so effectively.

- The OSS E/PO Program has been successful in building strong relationships with several large museums and science centers. It has also been effective in working with programs such as *Space Place* to gain entry into smaller museums, and to institutions such as zoos and aquaria, which have the capability to deliver small presentations. Smaller institutions reach individuals who may not have other access to space science. Creating more resources that do not require advanced technology or extensive physical space can be an effective strategy to reach U/U communities. Ideally, these resources should be adaptable enough to be used in a variety of settings.

- The OSS E/PO Program and its partners have created a variety of quality resources that can be useful to a range of users (teachers, museums, and the public), *if users can access them*. Resource distribution is a complex issue, requiring a multi-pronged approached. Discussions about partnering with NASA CORE or linking with commercial partners may lead to positive results, but as of this writing, there is still no means of producing and distributing products on an as-needed basis. Other options for distribution should be explored. Facing this challenge will likely require significant investment of both time and money, but is necessary if OSS is to reach students and the public in *all* communities.

- The OSS E/PO Conference provides a model for working with various groups to ensure that their voices are heard. There are many ways that the OSS E/PO Program learns *directly from users* what resources would be most useful. It is imperative that these channels for communications be substantially expanded and strengthened.

    - Meetings between E/PO developers and end-users (that is, educators in schools, museums, and other places where OSS resources are used) allow the development of a repertoire of approaches to formal education. To ensure effectiveness, it is important to include educational leaders and researchers in this process. Scientists who are interested in E/PO also benefit from attendance at such meetings.

    - Members of U/U groups have particular needs. For example, African Americans, women, visually-impaired students, and Native Americans face different challenges. The OSS E/PO Program has begun to explore the needs of these various groups, through the Minority Initiative and work with minority professional groups, but further conversation is necessary. The challenge of addressing the needs of multiple, diverse populations requires the allocation of funds and staff time.

    - The Internet is not only a useful tool for sharing OSS findings with the public, it can also be a useful tool for gathering data about what the public wants. At present, few OSS Web pages have easily accessible feedback mechanisms. Providing these would allow users to communicate their needs and highlight areas where Internet resources can be made more useful and more accessible.

APPENDICES

APPENDIX A: GLOSSARY OF ACRONYMS, ABBREVIATIONS, AND NASA CODES

AO: Announcement of Opportunity: a solicitation of proposals for mission funding

B/F: Broker/Facilitator: an organization that works regionally to support the mission and goals of the OSS E/PO Program; the B/Fs are part of the Support Network

Code E: NASA's Office of Equal Opportunity Programs

Code EU: NASA's Minority University Research and Education Division

Code FE: NASA's Education Division, part of the Office of Human Resources and Education (Code F)

Code S: The Space Science Enterprise (OSS)

CORE: Central Operation of Resources for Educators, a distribution system for multi-media resources

CTA: Chicago Teachers' Advisory

EDCATS: Education Division Computer-Aided Tracking System: A NASA-wide database of education activity

E/PO: Education/Public Outreach

ERC: Education Resource Center

Forum: An organization that supports and coordinates the development of E/PO resources related to one of OSS's four Themes (Solar System Exploration, Sun-Earth Connection, Structure and Evolution of the Universe, Astronomical Search for Origins); the Forums are part of the Support Network

GLPA: Great Lakes Planetary Association

HBCU: Historically Black College or University

MI: Minority Initiative/Minority University Education and Research Partnership in Space Science Initiative

NASA: National Aeronautics and Space Administration

NRA: NASA Research Announcement: a solicitation of proposals for Supporting Research and Technology funding

NSTA: National Science Teachers' Association

OMB: Office of Management and Budget, which is responsible for assisting the President in overseeing the preparation of the Federal budget and supervising its administration in Executive Branch agencies

OSS: Office of Space Science

OSS Education Council: A group created by OSS to ensure coordination of OSS E/PO efforts. It comprises the SN, OSS administration, and personnel from Code FE and Code EU

OSS E/PO Program: The individuals and organizations that participate in or contribute to the creation of OSS E/PO material, and all activities carried out in support of the OSS E/PO Strategic Plan

PD: Professional Development

PDF: Portable Document Format

PERG: Program Evaluation and Research Group, the outside evaluators who prepared this report

PI: Principal Investigator

SN: Support Network, comprising the Forums and B/Fs

SSERD: Space Science Education Resource Directory, a database of (currently electronic) E/PO resources created by or through the OSS E/PO Program

SSIT: Space Science for Illinois Teachers

STScI: Space Telescope Science Institute

SUNBEAMS: Students United with NASA Becoming Enthusiastic about Math and Science

T and R: Tracking and Reporting system: a database of OSS-specific E/PO activity

U/U: Underserved/Underutilized

APPENDIX B:
A STATEMENT ABOUT THE CULTURE OF AMERICAN EDUCATION AND THE CHALLENGES TO EDUCATIONAL CHANGE

Susan Baker Cohen
Program Evaluation and Research Group
Lesley University

White Paper Developed for the Office of Space Science
Education and Public Outreach Community
(work in progress)

As so many noted educators and researchers have observed, schools are complex environments and public education is an enormously complex undertaking. To think otherwise is to ignore the social, political, and economic influences that "come to school" with every child, teacher, and education-related program and organization.

My intent with this brief summary is to provide a highly abbreviated review of issues that those engaged in education improvement might want to consider as they plan their work. It is NOT my intention to provide a thoroughly researched review of the literature of education reform.

Publicly-supported education arose from constitutional principles for creating a democracy. It was strongly influenced and shaped by the industrial demands of the 1800s to create substantial numbers of workers who could support and sustain the industrial and economic efforts for US expansion. Educating the public was meant to create a baseline of literacy that would enable people to vote and work in factories. Educators are expected to be the analog of technicians, performing functions defined by others with materials designed largely by others for purposes decided largely by others, and measured by standards created largely by others.

Education decision-making is a top-down affair that separates the curriculum direction and selection from the majority of teachers who must implement and who are held accountable for student learning. In most districts in the country, curriculum materials for each subject area K–12 are selected in five-year cycles. Teachers are required by their districts to use those selected materials, but usually can supplement these with additional resources, as budgets allow. In general, teachers rely on their administrators to make the decisions about the specific curriculum content they must cover and its correspondence to national and state standards to which the system is accountable.

The fundamental challenge to changing education arises from the fact that there is little agreement within states and the country about how all of the components of the education system and process should relate to one another. The symbols of the current "reform" movement include (but are not limited to) the National Mathematics and Science Standards, The National Assessment Standards for Mathematics, and the 2061 Science Benchmarks. Educational change theories have included strategies that target the statewide educational system, coalitions of multiple districts, individual districts, and even individual schools. Research data continue to stress the reality that individual schools are the fundamental unit of change, the central concept that motivates the work of the Coalition of Essential Schools. Research has found that each school shapes its own culture and exerts pressure on all of its members to conform to that culture to accomplish its goals. In the case of education, all change is local, to adapt a well-known phrase.

> The search for generalizations in the sense of lawlike propositions that can be packaged and transferred from setting to setting is neither possible nor desirable in these kinds of renewal efforts . . . we can learn from these efforts and share this learning with others. But this is generalization of a much different sort. It is building heuristic understanding, developing and refining ideas that others can play with and reconstruct in their own settings. By accumulating what we call "cases of understanding," we can have an ever-expanding source of examples from which others can learn. (p. 4)[22]

While many districts in the country are experimenting with alternative models for addressing many of the challenges of change, the majority (including rural and urban districts) have little, if any, influence outside of their locality. One of the current indicators of change is curriculum program selection and implementation. Currently, publishers of what has been called NSF-supported and other standards-based curriculum materials/programs estimate that no more than 10–15% of all US school districts are really implementing these at any level of use.

Statewide tests are currently measuring students with little recognition about what students are actually learning in their curriculum, creating a false picture of student learning that has great social consequences. Test scores influence real estate values by suggesting that schools are effective in educating students, attracting the very families whose students are already successful. Low scoring students, on the other hand, fall into categories that correspond to research-based profiles, reinforcing commonly held stereotypes and assumptions about who can learn and be successful in school.

> The elements of a standards-based system are coming into place unevenly in states and cities across the country. Most states now have content standards,

[22] Sirotnik, K. (1999, April). *Making Sense of Educational Renewal*. Bloomington, IN: Phi Delta Kappa International. Online article retrieved from the World Wide Web: http://www.pdkintl.org/kappan/ksir9904.htm

> although their quality varies . . . Only a minority of states have established true performance standards, that is, descriptions and illustrations of the kinds of work students are expected to be able to do. Many states and virtually all school districts administer tests, and many use the language and rhetoric of standards in communicating with parents and the public about the results of these tests. But it is still rare that the tests used have been systematically aligned to the officially adopted standards. In some jurisdictions, an off-the-shelf norm-referenced test is used as part of a nominally standards-based system, with score points being used to establish "standards." . . . It is even more rare to find instructional materials and strategies well aligned to standards, and accompanied by systematic professional development. (p. 2)[23]

Complicating these realities is the current political and philosophical environment that has often pitted educators and content specialists, such as scientists and mathematicians, against one another. The focus of all of this energy is the not always enlightened discussion about the theory that best addresses or explains how people learn and the role of learning in our lives. Some people think the formal education system needs to be "reformed"; others feel that "improvement" is a more suitable ambition and achievable goal. Each of those words comes loaded with rich and complex justifications about which well-meaning and intelligent educators disagree.

Within science, the discussion about constructivism or constructivist learning has raised red flags. The conversation leads to impassioned indictments of scientists' motives, capacity for rational thinking, the value of their contributions to their fields, and the problem about how to best educate future scientists. The turbulence of the exchange in the public and science domains has caused numbers of educators to react negatively about changing their ideas and/or practices. Since the education wars are not yet won, it is not clear what direction will best meet the needs of the system. Many teachers and administrators throughout the country note that conducting business as usual may be the least harmful of all approaches.[24]

In addition to the above issues, the classroom is a complex and challenging place for both students and teachers. Most state education policies increasingly require that all children who can be, are included in the classroom with their age peers. In addition to addressing a wide range of physical needs, teachers know that the students bring to school a variety of learning differences, languages, capabilities, substantially different cultures and school achievement backgrounds. Many students have little English language proficiency; in some urban schools, the number of languages spoken may be as high as 50–100. Both

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[23] Briars, D. & Resnick, L. (2000, August) *Standards, Assessments—and What Else? The Essential Elements of Standards-Based School Improvement* (CSE Technical Report 528). Los Angeles: University of California, Center for the Study of Evaluation.

[24] Matthews, M. (Ed.). (1998). *Constructivism in Science Education: A Philosophical Examination*. The Netherlands: Kluwer Academic Publishers.

non-specialist classroom teachers and subject matter specialists have little training to address these problems. Most publishers provide few, if any, curriculum resources to support the diversity of students.

Many elementary and middle school classroom teachers, specialists, substitutes, and other school-based staff are not necessarily well educated in the subjects or areas for which they are held responsible. That fact is the result of multiple conditions, both historic and current. One such issue is that teacher certification requirements have been determined by each state. The certification requirements represented a state's best ideas about what their local school districts needed teachers to know and be able to do in order to teach students. Since most school districts in the country were considered to have control over the fundamental issues of curriculum and accountability, states were limited in their ability to ensure that all teachers certified were going to teach what they knew and knew what they would be teaching.

And there are other complicating conditions driving education.

Businesses are demanding that schools teach those skills and content that relate directly to the skills and abilities they need now and project for the future. Technology has become ubiquitous in society but not in schools. Creating technology-sufficient schools requires funding, which is often not available through the local school district budget. The addition of state and national technology-funding programs is often insufficient to install a districtwide system.

While it is hard to pin down numbers, the US DOE claims all schools in the country are ready for connectivity. In many cases, that means only that wiring is installed somewhere in the school district, but it does not guarantee that there are sufficient resources for students and teachers to take advantage of the riches technology can provide for a learning environment. Taking advantage requires that up-to-date equipment, wiring, peripherals, and software are readily accessible to teachers and students, and that both populations are well enough trained and practiced to take advantage of the technology.

A sample of some uses found in schools that are well furnished and prepared indicates that teachers and students conduct research on the Internet, participate in networks and listservs to reach scientists and other experts, keep personal journals and other records about teaching and learning, and access state-of-the-art software that allows for high-level thinking and learning. Teacher training and ongoing technical support for sustaining the technology-mediated and -supported learning is expensive. Most school districts that have embraced technology do only a modest amount of both. Some do neither.

Remedies for many of these issues are postulated in a range of systemic change theories that name conditions deemed to be both necessary and sufficient to create the education needed for the future of our county.

As has been already noted, there is as yet little agreement about those theories and remedies. In fact, dialogue about creating the most effective schools has been historic, and change slow, as has the effort to ensure that changes made are sustainable and can produce evidence of effectiveness.[25]

> . . . unless education reformers and practitioners at all levels are aware and make use of some of the important lessons from the history of previous efforts [for change] all bets are off. We can't dither at this time over fine points, but if our designs for New American Schools are based on quick impressions and seat of the pants judgments uninformed by the lessons of history, a great opportunity will probably be lost as history repeats itself. (p.14)

Theorists, researchers, and interested thinkers have drawn from some of the more advanced theories regarding systems and their management to operationalize the structures and systems they think are required to deliver state-of-the-art education for the future. A sampling of theories includes, but is not limited to, Chaos Theory, Organizational Change theories including Systems Dynamics, Quantum Theory, and Social Psychology. While there is little agreement about how to best proceed in a country that favors local control, creating models of best practices seems to the most recent approach to guiding the change process. But best practices are in the eye of the beholder, measured in most states solely by student test scores.

Seymour Sarason made it clear *in Revisiting the Culture of the School and the Problem of Change* (1996) that the origins of education change come from social forces, not from within the school, and therefore control the nature of the changes that are socially acceptable to a national education endeavor.

> . . . the public schools have always had a transactional relationship with their communities: affected by them and in turn affecting them. (p. 2)

He notes that our society tends to identify schools as a set of buildings or locations, as if the activity of learning was confined to and by those buildings. The consequence of that thinking is that our society tends to look only within those buildings to find the causes for school's insufficiency rather than understand that it is society that determines what happens in schools. He notes:

> The major limitation is that such an approach obscures the implicit and explicit transactions between school and community. *That limitation goes unrecognized until, either from within or without, an attempt is made to effect a significant change in the schools.* Then it becomes glaringly apparent that what goes on is

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[25] Sashkin, M. & Egermeier, J. (1991 Draft). *School Change Models and Processes, A Review of Research and Practice (*Article prepared for presentation at AERA annual meeting, 1992). Office of Educational Research and Improvement.

> not explainable only by riveting on what goes on *in* schools. We tend to be unaware that we use the concept of the encapsulated school system in ways that blind us to the daily realities of the school-society relationship. (p.2)

The reality of educational change is that it is a collective endeavor, requiring the collective intelligence of every citizen. We will never all agree on what constitutes "best practices." The nature of our diversity and the ongoing influx of groups that have differing ideas about education and their children's futures make that impossible.[26] What we can do as a society is come to a consensus that education reform is more about continual alteration to the process of teaching and learning than it is about coming to a final resting point. Managing information is the most pressing challenge for the near future. Who knows what the longer term will bring?

Our education system must be a locus for inquiry and conceptual understanding for all of the nation's children. Historically agreed upon information must not be all there is in classrooms. Human learning has not changed over the last several thousand years. Earliest humans were clever enough to invent mathematics, astronomy, writing, art, music, philosophy, agriculture and manufacturing. They did not necessarily need schools as we know them now to accomplish all of those things. In fact, we continue to hold Socrates as one model of best practice in the academy, if not in the K–12 classroom.

But the majority of US schools still teach students using practices that we now know will produce a good percentage of students who will be bored and disinterested in school and identify learning as synonymous with remembering and recitation. Students' non-engagement in school results in all of the problems that have been documented since the period of the l950s when James B. Conant reported to the public on the state of schooling in *The American High School Today, A First Report to Interested Citizens* (1959). Maintaining ineffective practices, systems, and beliefs will ensure the maintenance of past and current problems. Creating an educational consensus in the country requires tremendous leadership because it is the society, not those who work in schools, that determines what goes on in the classroom. But consensus-building about public education lies at the heart of true educational improvement.

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[26] Sarason, Seymour. (1996). Revisiting the Culture of the School and the Problem of Change. New York: Teachers College Press.